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Editorial: Data-driven approaches for efficient smart grid systems

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Editorial on the Research Topic
Data-driven approaches for efficient smart grid systems

Smart grid systems (SGSs) are leading the modernization of energy infrastructure by integrating advanced technologies to improve efficiency, reliability, and sustainability. These systems demand sophisticated tools to address their complexity, with forecasting and optimization being crucial areas of focus. Machine learning (ML) techniques, including both traditional neural networks and advanced deep learning approaches, play a significant role in tackling the intricate challenges of SGSs. These methods enable accurate forecasting, which is essential for predicting electricity demand, renewable energy generation, and system loads. By supporting informed decision-making and efficient resource allocation, ML provides both theoretical contributions and practical applications for smart grids. This Research Topic, *Data-Driven Approaches for Efficient Smart Grid Systems*, explores the innovative use of machine learning to address challenges specific to SGSs. Forecasting is central to these efforts, as it forms the basis for understanding and managing the complex dynamics of SGSs. While traditional methods have demonstrated promise, they also highlight limitations in adaptability, scalability, and precision, particularly when addressing the evolving needs of modern smart grids. These challenges call for advanced algorithms that integrate diverse data sources, capture spatiotemporal relationships, and account for uncertainties.

The Research Topic is organized into four thematic areas ("forecasting and prediction techniques", "optimization and scheduling in power systems", "data quality, validation, and identification", and "research trends and evaluations in energy systems"), which highlight the variety of approaches and contributions from the 13 papers accepted.

The first area focuses on forecasting and prediction techniques, essential for managing renewable energy sources and optimizing grid operations. Yang et al. presented "*A Study of Short-Term Wind Power Segmentation Forecasting Method Considering Weather on Ramp Segments*," introducing a hybrid method that combines LightGBM-LSTM for non-ramping segments and CNN-BiGRU-KDE for ramp segments, achieving improved accuracy under extreme weather conditions. Zhao et al. proposed "*Photovoltaic Output Prediction Based on VMD Disturbance Feature Extraction and WaveNet*," which integrates variational mode decomposition with WaveNet, achieving a mean absolute percentage error of 6.94%. Huang et al. introduced "*Ultra-Short-Term Prediction of Microgrid Source Load*

Power Considering Weather Characteristics and Multivariate Correlation," presenting a joint forecasting model that uses multivariate correlation techniques and neural networks to enhance prediction accuracy for microgrid sources and loads. Peng et al. proposed "*Short-Term Wind Power Prediction and Uncertainty Analysis Based on VDM-TCN and EM-GMM*," using a VDM-TCN-based method to reduce RMSE errors and Gaussian mixture models for uncertainty analysis. Chen et al., in "*A Physical Virtual Multi-Graph Convolutional Coordinated Prediction Method for Spatio-Temporal Electricity Loads Integrating Multi-Dimensional Information*," developed a multi-graph convolutional network that models spatiotemporal dependencies, leading to more accurate short-term electricity load forecasts.

The second area explores optimization and scheduling in power systems, which are critical for ensuring cost-effective and reliable operations. Lu et al., in "*Optimal Scheduling of the Active Distribution Network with Microgrids Considering Multi-Timescale Source-Load Forecasting*," presented a hierarchical scheduling strategy that combines CNN-LSTM forecasting with a two-layer optimization framework, reducing operational costs and network losses. Jain and Gupta contributed "*Optimal Placement of Distributed Generation in Power Distribution Systems and Evaluating the Losses and Voltage Using Machine Learning Algorithms*," introducing a hybrid ML approach that combines support vector machines, random forest, and radial neural networks to optimize distributed generation placement, improving voltage profiles and minimizing power losses.

The third area addresses data quality, validation, and identification, which are fundamental for the success of ML applications in SGSs. Jiang et al., in "*A Multi-Task Learning-Based Line Parameter Identification Method for Medium-Voltage Distribution Networks*," proposed a framework that uses graph attention networks and multi-gate mixture-of-experts to improve line parameter identification. Hu et al. developed "*Bad Data Identification Method Considering the On-Load Tap Changer Model*," a two-stage method that addresses nonlinearities introduced by on-load tap changers, improving state estimation reliability in distribution networks. Cao et al., in "*Intelligent Substation Virtual Circuit Verification Method Combining Knowledge Graph and Deep Learning*," proposed an approach combining knowledge graphs with deep learning to improve the accuracy of virtual circuit validation in substations. Li et al., in "*Channel Prediction Method Based on Data-Driven Techniques for Distribution Automation Main Stations*," introduced an adaptive broad learning network for communication channel state prediction, enhancing transmission quality.

The final area examines research trends and evaluations in energy systems, focusing on broader developments and identifying gaps in energy system research. Jain and Gupta, in "*Evaluation of Electrical Load Demand Forecasting Employing Various Machine Learning Algorithms*," evaluated short-term power load prediction using 5 years of data from the Chandigarh UT electricity utility. The study compares algorithms such as LSTM, SVM, ensemble classifiers, and deep learning methods, concluding that LSTM achieves the lowest prediction errors, outperforming SVM by 13.51%. Kizielewicz, in "*Onshore Power Supply: Trends in Research Studies*," examined the development of Onshore Power Supply (OPS) systems in ports to reduce exhaust gas emissions. By analyzing technical, economic, and logistic factors, the study identifies key research gaps and outlines a roadmap for future exploration.

The contributions in this Research Topic demonstrate the potential of machine learning to advance smart grid systems. By addressing challenges in forecasting, optimization, data validation, and broader research trends, these papers provide valuable insights and practical solutions for improving the efficiency, reliability, and sustainability of SGSs. This collection reflects the growing importance of data-driven approaches in bridging the gap between research and real-world applications. We hope these works inspire further research and collaboration across academia, industry, and policymaking to enhance the capabilities of smart grids and support global energy sustainability.

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